

Baryon Oscillations in the Large Scale Structure

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Abstract. We study the possibility for an observational detection of oscillations due to baryons in the matter power spectrum and suggest a new cosmological test using the angular power spectrum of halos. The *standard rulers* of the proposed test involve overall shape of the matter power spectrum and baryon oscillation peaks in projection, as a function of redshift. Since oscillations are erased at non-linear scales, traces at redshifts greater than 1 are generally preferred. Given the decrease in number density of clusters at high redshift, however, one is forced to use tracers corresponding to galaxy groups and galaxies themselves.

1. Introduction

There is now increasing evidence for the presence of oscillations in the angular power spectrum of cosmic microwave background (CMB) anisotropies. The matter power spectrum of the large scale structure also contains a signature of baryons in the form of oscillations; the amplitudes of oscillations, however, are significantly lower with fluctuations at the level of $\sim 5\%$ for Λ CDM with widths of order $\Delta k \sim 0.02 \text{ h Mpc}^{-1}$. For an unambiguous detection, 3d surveys should have resolution scales greater than $L \sim 2\pi/\Delta k \sim 300 \text{ h}^{-1} \text{ Mpc}$ in all three dimensions. In 2d, oscillations can also be detected via the projected power spectrum. The 2d power spectrum requires no precise redshifts and can be constructed with halos detected in upcoming wide-field lensing and SZ surveys.

Following our suggestions that the angular power spectrum of halos can be used as a probe of cosmology (Cooray et al. 2001), projected oscillations provide a new cosmological test; this is similar to the measurement of the angular diameter distance to the last scattering surface using the first acoustic peak in the CMB anisotropy power spectrum.

2. Halo Clustering as a Probe of Distance

The angular power spectrum of halos in a redshift bin is a projection of the the halo number density power spectrum

$$C_l^i = \int dz W_i^2(z) \frac{H(z)}{d_A^2(z)} P_{hh} \left(\frac{l}{d_A}; z \right), \quad (1)$$

where $W_i(z)$ is the distribution of halos in a given redshift bin normalized so that $\int dz W_i(z) = 1$, $H(z)$ is the Hubble parameter, and d_A is the angular diameter

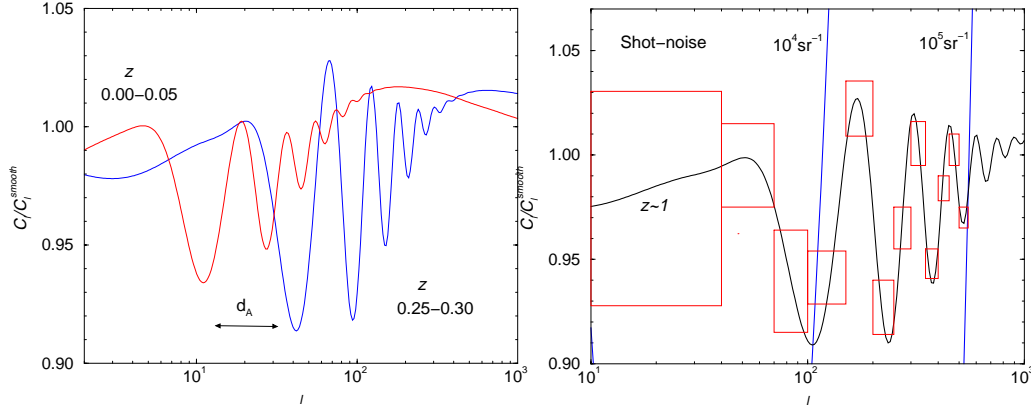


Figure 1. *Left:* The normalized power spectrum of halos at $z \sim 0.05$ and $z \sim 0.3$. The shift in oscillations is due to projection and correspond to change in distance between the two redshifts. *Right:* Expected errors for the oscillations due to sample variance alone. The shot-noise contribution due to the finite number of tracers are shown with a line. One requires 10^5 sr^{-1} source or more per z -bin for oscillation detection; this corresponds to a mass scale of $\sim 10^{13}$ at $z \sim 1$.

distance in comoving coordinates. Note that $W_i(z)$ comes directly from the observations of the number counts as a function of redshift.

The underlying linear power spectrum of density fluctuations, traced by halos, contains two physical scales: the horizon at matter radiation equality $k_{\text{eq}} = \sqrt{2\Omega_m H_0^2(1+z_{\text{eq}})} \propto \Omega_m h^2$, which controls the overall shape of the power spectrum, and the sound horizon at the end of the Compton drag epoch, $k_s(\Omega_m h^2, \Omega_b h^2)$, which controls the small wiggles in the power spectrum. The angular or multipole locations of these features shift in redshift as $l_{\text{eq},s} = k_{\text{eq},s} d_A(z_i)$. We propose the following test: measure C_l^i in several redshift bins and, using the fact that $l_{\text{eq},s}$ scales with $d_A(z_i)$, constrain the angular diameter distance as a function of redshift. Unlike the case with CMB, we can use tracers over a wide range in redshift and measure the distance as a function of redshift, or redshift bin.

The test can be affected by two ways: (1) non-linearities generally erase the baryon oscillations and at $z < 1$ oscillations are generally affected. At low redshifts, one can use the test with the overall shape defined by k_{eq} . (2) The tracer bias can be scale dependent, but for mass selected catalogs via lensing or SZ, bias can be studied with simulations.

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References

Cooray, A., Hu, W., Huterer, D., & Joffe, M. 2001, ApJ, 557, L7.